Innovation, Operational Control and the Management Information System

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The success of a business depends in large part on its ability to both control its current operations and rejuvenate itself through innovation. Control, if understood as persistent conformance to a given plan, however, can easily become the enemy of change through innovation, and so its presence may endanger an organization's future. It may bring about a separation of the organization into two neat and hostile groups each of which views its interests as incompatible to those of the other. The financial people and managers may thus be viewed as the oppressors whose only interest is to guarantee the integrity of "the plan" through the use of budgets, standards, controls, and robot-like behavior. No doubt such a system, to the extent that it does not allow any variations from the plan, will stifle innovation at all levels below the planning level. Unless, therefore, the planners are omniscient and have an unbounded insight in the details of operations, stagnation will ensue. This point has been fervently argued by proponents of participative goal setting,[1] but more recently also by accountants.[2]

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[1]See: Chris Argyris, "Human Problems with Budgets", Harvard Business Review, Vol. 31, No. 1, Jan-Feb. 1953, pp. 97-110; Maison Haire, "Philosophy of Organization" in Management Organization and Planning, D. M. Bowman and Fillerup, F. M., Eds. McGraw-Hill Book Company, Inc., New York 1963, pp. 1-16; Douglas McGregor, The Human Side of Enterprise, McGraw-Hill Book Company, Inc., New York 1963, especially pages 33-49 where he expounds "Theory X" and "Theory Y".

[2]For example see Robert N. Anthony, Planning and Control Systems - A Framework for Analysis, Division of Research, Graduate School of Business, Harvard University, Boston, Massachusetts 1965, pp. 28-29.

The tighter control can be, the greater usually is the confidence placed in a standard, and the greater the propensity may be to stifle innovation. Since operations as supervised by middle or lower management (in the following called operations management) lend themselves to standardization much more than top managerial activities, the conflict is particularly real at the operational level.

Our paper will address itself to the thorny problem of fusion of the preconditions and aims of control and innovation. We will try to point out directions in which improvements in the organization structure and the management information system may be sought in order to reduce or alleviate the apparent conflict between controls and motivation for change. In other words our goal will be a system which retains the advantages of control through standardization, but at the same time encourages innovation. With the above as an introduction, we will now look at standardization and analyze its purpose and attributes.

Purposes and Characteristics of Standardization

Among the foremost tasks of top management are:

1. The initiation of new activities

2. The establishment of policies for setting standards for operations (and, in many cases, supervision of the setting of such standards, as in the case for example when they are set by an industrial engineering staff rather than by the operating departments themselves)

3. The management by exception, that is to say, the monitoring of deviations for singling out the operations which require management attention (are out of control)

Standardization, we hold, is instituted by top management for two main reasons. First, in order to increase the expected value (mean) of the process by reducing negative deviations from the mean (which deviations would have occurred without this type of control); second, to reduce uncertainty for the process and the total organization, through reduction of variances.[3] Quite aside from any psychological aversion to uncertainty, reduction in uncertainty is desirable because it permits other activities to be planned better, be they other standard operations or innovative in nature. We shall have occasion a little later on to come back to this point.

In order to lend themselves well to short-run control, operations must possess certain desirable if not indispensable characteristics. These are as follows:

1. Operations must be standardizable - As the information and control system is addressed to a given benchmark, the operations must be amenable to standardization, or at worst to rough estimation, otherwise there will be no guidepost on the basis of which one can measure deviations of performance.

2. The process should be stable - In order that we may be able to arrive at a standard for the control system in the short run, the process which we are interested in controlling must be stable, otherwise it will not be amenable to characterization. If standards are shifting (though predictably) for technical reasons in the short run, they are far less useful for control purposes especially if we wish to measure the impact of standards and controls on motivation.

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[3] Variance may be understood as 'accounting variance', that is to say a statistical deviation, or a statistical variance i.e., deviation squared. Since they both move together, we will not for most of the exposition distinguish between the two unless it is essential. Our statements here assume that the standard is set at the mean, but this is not vital for our general arguments.

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3. Optimizing techniques should exist - To the extent that standards carry the implications of norms, there should exist some method for determining the "optimal"[4] technique of operations. Otherwise, though it may be possible to select a method of operations and set standards for it, there would be little confidence in their usefulness and little incentive to stick to them.

Given the above conditions for the existence of a meaningful short-run control system, the system can provide what is known as management by exception. That is to say, it can be instructed to provide managers with signals of significant deviations only and enable them to address themselves to problems of short-run control only whenever it is necessary. Such a system can be as complicated and sophisticated as the sensitivity of managerial decisions requires.[5] In particular, it can be designed to:

(a) Indicate whether costs are under control

(b) Locate deficiencies in control efforts

(c) Facilitate identification of causes

(d) Locate the decision locus which caused the deviations

(e) Generate information relevant in some cases for pricing decisions, intercompany transfers under responsibility center organization, etc.

There are many potential advantages to standardization for managers especially at the operational level.

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[4]Within the existing state in technology.

[5]For a description of a simple probabilistic system see: Zenon S. Zannetos, "Standard Costs as a First Step to Probabilistic Control: A Theoretical Justification, an Extension and Implications", The Accounting Review, Vol. XXXIX, No. 2, April 1964.

First of all, the use of dollar figures allows managers to assess the magnitude of deviations in homogeneous ~~terms~~. Then the very process of setting standards leads to a better understanding of the technical characteristics of operations, of the process itself, as well as of the relevant environment, and so does the observation of the environment and the comparison of the implications of its newest state with the standards. All this in turn is reflected in improved performance and standards. Thus standardization can lay the basis for improvement through specialization even at the level which is controlled through standards. Whether this potential will be exploited, depends on the motivation of the managers and workers at the operational level. The information and control system has the capacity, given the standards, to generate the appropriate motivating signals in terms of deviations so one may consider this as an additional benefit of standardization at that level.[6]

Let us elaborate next on what "control through standards" means to layers of management above the one at which such control is instituted. We best

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[6]The esoteric issues in motivation which are quite critical in the setting and use of standards and budgets will not be directly the subject of this discussion. Although some encouraging work has been done there are still many unresolved issues and much more empirical work is necessary before we move from the present hypotheses generation stage. For a fruitful discussion see (in addition to Argyris and McGregor); Neil C. Churchill, Behavioral Effects of an Audit: An Experimental Study, Ph.D. Thesis, Ann Arbor, University of Michigan 1962; N. C. Churchill, W. W. Cooper and Trevor Sainsbury, "Laboratory and Field Studies of the Behavioral Effects of Audits", in Bonini et. al. (Eds.) Management Controls: New Directions in Basic Research, New York, McGraw-Hill Book Company, 1964; Andrew Stedry, Budget Control and Cost Behavior, Englewood Cliffs, New Jersey, Prentice-Hall, 1960; A. C. Stedry and E. Kay, "The Effects of Goal Difficulty on Performance: A Field Experiment", Sloan School of Management, Massachusetts Institute of Technology, Working Paper 106-64.

start with two examples: The less certain the magnitude of the output of an operation in a given period, the higher and more costly buffer inventories between it and the subsequent operation may have to be in order to avoid chaos and disaster, or the more frequent the revision of the plans of subsequent operation must be, which is costly too. In other words the greater the uncertainty inherent in the plans and operations of a given critical unit, the greater tends to be the cost of the system which will shield other interdependent plans or units from this instability. Such shielding from variations in the "external environment" is necessary to allow each unit to plan its own operations efficiently. Thus, uncertainty reduces the expected value of all operations combined. Second, the less certain we are about the level and costs of an operation in a given time period, the less certain we are about the financial resources flowing from the operation and required by it, and the less certain we are about the resources available for long-range plans and innovation, such as construction of a new plant, marketing of a new product and the like. This may force curtailment or postponement of such long-range activities, costly borrowing, or arrangement of standby credit which also is not free. We see, therefore, that uncertainty about one process translates itself ultimately into the reduction of the expected outcome (mean) of other processes that somehow are dependent on it.[7]

Expressing the above notion in another way, we can say that standardization provides temporary stability at the operational level enabling higher management to go into innovation or more complicated and ambitious planning

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[7]Uncertainty about the income of the firm may also result in a lower stock price, which again is likely to be considered undesirable for management and stockholders.

and, consequently, to venture into uncertainty of a higher magnitude and pay-off. In effect, the overall level of uncertainty content in managerial planning may not be reduced with the standardization of certain operations, but will certainly be of a different nature, or may have shifted to a different problem of greater import for the total organization. Standardization thus is a means to an end, namely, a means to problem solving and innovation.

Of course, management can also use standardization to stabilize operations and expectations at all levels in the hierarchy, transfer control to an automated system and thus be able to lead a complacent life, at least temporarily. Such a spirit generally will permeate to lower managerial levels when top management, consistent with the goals of a quiet life, puts more emphasis on small deviations from the standard rather than on the use of such standards as a springboard for increases in the total outcome. To an observer at the operational level it then appears that the standard has become for management an end in itself. Such use of standards is likely to lead to a rude awakening after some time, as profits turn to meager returns and possible losses.

The returns that accrue to the entrepreneur tend to be commensurate with the risk and uncertainty that are inherent in his planning and operations. An operation that is reduced to a standard is emptied in large part of risk and can be copied more easily. The very existence of a meaningful standard indicates that essential knowledge about the operation is communicable. Patents expire, secrets about processes or resources on which monopolies are held transpire, substitutes tend to be found, and drops in transportation costs endanger monopolies derived from location. Unless, therefore, very

high capital requirements obstruct entry, high returns from a copiable process will invite strenuous competition and the return from operations will be extensively reduced. Where capital requirements are high, the stagnating firm may succeed in protecting itself somewhat longer but the inevitable will

I would certainly be worried if the inevitable didn't come

come. In fact the longer the artificial props are sustained the more painful the process of rehabilitation, particularly in an industry characterized by heavy capital intensiveness. Obviously it is not easy for a firm to raise large amounts of capital at a time when it is in the midst of crippling competitive pressures.

To sum up, in the absence of contrived scarcities which can be maintained over time, the return that the market will allow on operations where technology can be imitated by competitors or potential competitors at will, cannot be expected to be greater than a financial rent. This shows us that standardization, if it stops with a short run uncertainty elimination, is a sign of weakness and harbors potential troubles. To put it in the words of Thomas Fuller: "Security is the mother of danger and the grandmother of destruction."

The process and consequences of learning, standardization, and the innovation that we analyzed above, can be also put in terms of the levels of the mean (standing for the average results from operations) and variances (standing for uncertainty[8]) as follows:

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[8]Strictly, speaking any property pertaining to the shape of the probability distribution might be considered relevant by a rational (consistent) decision maker. In order to keep the discussion simple we will restrict ourselves to the (first and) second moment, namely, variance, incorporating in the latter all the relevant desirable properties.

Assume that at time t_o we have instituted a new process (or product) with mean $\bar{x}_o$ and variance $\sigma_{x_o}^2$. After learning enough about the process and having standardized it, the mean and variance are, let us say, $\bar{x}_1$ and $\sigma_{x_1}^2$, respectively with:

$$\bar{x}_1 > \bar{x}_o$$

$$\sigma_{x_1}^2 < \sigma_{x_o}^2$$

holding.

In other words by means of learning and standardization, the average outcome increases and it is more certain. This assumes that competition and other environmental factors have not changed. If now management decides to innovate, it does so in the expectation that:

$$\bar{x}_2 > \bar{x}_1$$

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$$\sigma_{x_2}^2 \gtrless \sigma_{x_1}^2 < \sigma_{x_o}^2$$

A successful innovation implies that the new mean $\bar{x}_2$ is greater than $\bar{x}_1$, but nothing can be said with certainty about the level of uncertainty surrounding the new process. It could be greater, equal, or less than before. If the experiment fails, then management can revert to its previous technology and operations are carried on as before with $\bar{x}_2 = \bar{x}_1$.

We must stress at this point that expectations of a greater mean than before are not sufficient, although necessary, for the implementation of an innovation. The increase in uncertainty, as measured here by the relationship between the variances $\sigma_{x_2}^2$ and $\sigma_{x_1}^2$ might be so large in the opinion of management that the change is undesirable in spite of the increase in expected returns. Not tr

Let us now suppose that management decides not to innovate, and that competition moves in. If the competitors simply imitate the existing technology then the cost of operations may not change but net revenues $\bar{x}_3$ may fall due to competitive pressures. The variance of the established firm may move either way.[9] But even if it is reduced in absolute terms, that is to say $\sigma_{x_3}^2 < \sigma_{x_1}^2$, still the fluctuations as measured by the coefficient of variation will in all probability be greater than before, that is to say $\sigma_{x_3}/x_3 > \sigma_{x_1}/x_1$, because of the relationship between x_3 and x_1 .

So, if management and shareholders measure risk in terms of percentage variations, inaction most probably will not only decrease the expected returns but also increase relative uncertainty.

Finally we take the case where both the competitors and the established firm innovate. In this case, nothing can be said about the relationships

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[9] If one starts from a state of administered prices the variance will most likely increase and then start decreasing as the market approaches the theoretical state of perfect competition with minimum necessary returns.

between the new $\bar{x}_4$ and $\bar{x}_1$ or $\sigma_{x_4}^2$ and $\sigma_{x_1}^2$. We can only make the trivial remark that (a) the entry of other firms will affect the established firm detrimentally, at least in the short run, and (b) the established firm will be better off with the innovation than without given $x_2 > x_1$. ? ?

Innovation, Standardization and Programming

Let us now look at some of the differences between innovative activities at the top and the operations level of management, and point out some undesirable consequences of the misuse of standardization. In the process it will become clear, we hope, that the mechanistic characteristics of efficient and inefficient systems that use standardization are not very different, yet the results are.

Major innovations, such as the choice of a new product line to be produced and/or marketed, a decision to build a new plant including the determination of its size, location and technology; penetration of new areas; and the setting of the level and direction of research and development not only require top management's approval, they also generally originate at top levels or in staff departments immediately under their guidance. Furthermore, in the initial stages of implementation, the activities remain the responsibility of top management rather than that of managers at the operational level. All these types of activities have one characteristic in common in that they do not lend themselves easily to programming. To be sure, progress has been made in this direction especially in the last decade. The analysis of capital investment proposals, for example, not only has been pushed much further, but industry has come to accept more and more refined methods, such as the

use of Linear Programming, PERT and Critical Path Scheduling in resource allocation decisions. On a more simple level, endless checklists are used for example in examining which area is best for location of a plant. Still compared to the activities of lower management, top management's tasks are less well structured, because top management through planning fixes most of the structure within which lower level decisions are made. Furthermore, we might even say that once an activity has been carried forward by top management to the point that it is programmable, it should be turned to operations management, or even to an automatic control system. For example, after a plant has been completed and trial runs have been made the plant is normally turned over to the responsibility of operations management. It is in this way that top management is freed from programmable tasks to undertake long-range planning and broad innovation.

Finally, top management's activities, as compared to those undertaken at lower levels, are more important in terms of the resources committed, the length of time for which they are engaged, and, most relevant for us here, the scope and the number of departments likely to be affected. Consequently, an innovation that is conceived at the top, often harbors important consequences for departments other than those in which it is most immediately applied. This, of course, does not imply that top managers _do_ _not_ get involved in innovating activities that affect only one department. What we wish to stress is that they _should_ _not_ under normal conditions do so. Rather, they should develop the environment which will properly motivate local management to innovate at the departmental level since top managers are not as knowledgeable about the structural relationships between inputs and outputs at low levels as local managers are. In cases where more than

one department is involved in the innovative experiment, top management may take the initiative because the lack of local knowledge is often more than compensated by top management's grasp of interdepartmental functional relationships.

For comparison, let us look at the types of improvement we would hope a well run operations department would carry out. These include:

1. Introduction of new processes to make the same products

2. Experimentation with changes in the product which do not impair its saleability or value to the user but reduce the cost of manufacturing

3. Experimentation with the process to improve the quality of the product

4. Experimentation with the process in order to reduce the cost per unit produced or to increase output per unit time, or yield per unit of materials used, etc.

5. Factor substitution in response to new factors becoming available, or, more commonly, in response to a relative shift in factor prices[10]

The above tasks are more programmable than those ordinarily carried out by higher management in the sense that the results are more predictable. Even

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[10] For a most ingenious proposal how to encourage within a standard cost system operations management to adjust itself to changing factor prices in the best interest of the firm, see Myron J. Gordon, "The Use of Administered Price Systems to Control Large Organizations," in Charles Bonini et. al., Management Controls: New Directions in Basic Research, McGraw-Hill Book Company, New York, 1964. Ordinary stable standards shield operations management to a large extent from changes in the environment. This, of course, is helpful both in directing the operations of the department and in evaluating the performance of the manager. Gordon's scheme manages to retain these advantages, and in addition provides information for motivating managers to better adjust to changes in price ratios.

where such is not the case, as we have previously mentioned, the effects tend to be less important in terms of both scope and time span over which their impact is felt. It is precisely this characteristic which should encourage management to experiment at low levels. The worst of consequences at the departmental level, let us say, in general will be less disastrous than an experiment by top management that miscarries, even when it is applied only to that department.

If the arguments that we present here are valid, then the information system of the firm should attempt to provide signals that motivate innovative behavior at low levels. It must provide information for design and analysis of experiments and cause and effect relationships. It must be a medium for learning and two-way communication, rather than a means for thermostatic control and an automatic mechanism for remedial action in the short run. Furthermore, it follows that the greater the expected consequences of decisions the more careful management should be in its experimentations and the more elaborate should be the information system for monitoring plans and operations.

In contrast to the above, we normally find that most of the energy of the information systems is spent on strict short-run control, with little or no effort devoted to the planning requirements of management. Deviations from standards, or, more generally speaking, from predicted outcomes, are used by the lower tiers of management mostly to initiate remedial action, and by higher management to evaluate lower management's performance. The danger is real that top management overlooks the probabilistic nature of variances and acts upon a variance that is not significant in a statistical sense. But even if it is (and is not due to lower management's experimentation)

the emphasis should be on understanding the underlying processes that generate it. If management requires an explanation that focuses on the actions which will eliminate such future occurrences they will put operations management in a defensive position.

This state of affairs in itself need not discourage lower management from innovating. Only when managers at lower level are made to expect few benefits for themselves whenever the mean of the process is increased or favorable variances occur and when "management by exception" is understood by higher management to mean punitive action at the appearance of (occasional and inevitable) unfavorable variances, is the system loaded against innovation at levels where unsuccessful experimentation carries the least risk for the enterprise as a whole. If the workers or managers of operations know that the only thing top management is watching and the only thing it cares for is for subordinates to meet the standard, for sure the results will be such as to justify these expectations. To the outsider (and not only to him) at this point it may appear that the standard has become a goal in itself, and that top management has abdicated its managerial responsibilities in favor of a system that instills automatic-response behavior and discourages thinking.

Top management's strict adherence to standards may be the outflow of its strong aversion to soul searching as well as risk, in which case we can do little except point out as we have done that it may be self-defeating in the longer run. Alternatively, it may well be that top management has translated its own goals into subgoals improperly--subgoals that are to be executed by its subordinates--and has structured its rewards inconsistently

with the goals it wants to pursue. The consequences of all this may at best be a stifling atmosphere at the bottom and a fair amount of innovative activities at the top. These activities nonetheless may not be successfully implemented due to negative attitudes existing at lower levels.

It is interesting to note that middle management occasionally succeeds in satisfying its own desire to innovate even in the face of an apparently (or genuinely) oppressive or regimentative top management. If a storable product is well standardized, all production in excess of standard may not be reported but instead stored in clandestine inventories to be used whenever production falls below standard.[11]

Once a sizeable inventory has been accumulated, local management may attempt a change in the process since there is enough surplus material to feed production during the shakedown period. If the inventory is nearly depleted before the new process yields at least as much as the old one, either the experiment is judged to be a failure or its continuation is postponed until the re-instated original process has again yielded material for further experimentation. Top management may even tacitly condone such practice since (a) it facilitates planning or decoupling of subsequent operations, (b) the costs of carrying such inventories does not appear explicitly on the company's books to draw attention, and (c) they do not have to relax temporarily the standards for departments that want to experiment, but can treat all of them alike.

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[11]To stay within our mathematical nomenclature: reported σ_x is kept (on purpose) below actual σ_x and an improvement in actual $\bar{x}$ is delayed in the report.

The clandestine inventory device has fairly obvious limitations. First of all, its applicability is restricted to non-perishable products either of standard inventoried items or of job-order items before they reach the point of specialization. Second, it can be instrumental only in changes which require quite minor outlays for equipment or additions to the workforce, because otherwise top management approval must be sought. Third, there is nothing in this method that channels the firm's resources into the most promising projects. Fourth, there is nothing to guarantee that it will ever be used. For example the surplus inventories may be used for supporting leisure.

Patterns of adaptation to top management pressure that are far worse for the firm are found in companies where production scheduling is part of the responsibility of the operations manager. The cost of some processes or products are better under control than those of others. If, say, in the first half of the reporting period operations management sees a strong variance emerge, they can schedule for the second half operations that are well under control and that regularly show a variance with the opposite sign. Such behavior, while shielding operations management from the inquisitiveness of top management empties the variances of their meaning and may lead to inefficiencies in production scheduling.

Steps Toward Encouraging Change within Standardized Settings

What steps then should top management take to encourage innovation within an organization while retaining the advantages of standardization in so far as these are useful in the long run? Clearly, mere toleration of innovative

activities at the lower ranks of the hierarchy as outlined in the preceding paragraphs is not sufficient, and the top administrators of even passably well managed firms are well aware of this. Some of the alternatives available to management are:

1. Creation of Specialized Innovative Units. While appreciating the importance of innovation but not wishing to relax strict short-run controls, top management may delegate all innovative activities to staff groups, often called "Research and Development", "Industrial Engineering", "Methods and Standards", "Operations Research", or "Economic Evaluation". Such exclusive arrangements are not satisfactory for the following main reasons: (a) A schism and friction is often created between line and staff groups, so the probability is substantial that whatever the staff people suggest may either be summarily discarded or else if it is applied, the operating groups may make certain that the experiment fails. (b) The staff groups may be viewed as the policemen of top management and their utility within the firm may, therefore, be completely jeopardized. (c) Such an approach to innovation foregoes most of the advantages of standardization. As we have previously argued the latter should be used as a stepping stone toward further innovation, especially in cases where detailed knowledge of the process or the environment within which operations take place is vital. Special staff groups do not as a rule possess intimate knowledge of local conditions and cause-effect relationships. (d) Finally, the complete separation of operations and innovative activities leads to a waste of whatever creativity exists within operating units.

2. Periodic Solicitation of Ideas. Many firms have established procedures for soliciting improvement proposals once a year at the time that they prepare their annual capital budgets. In these proposals operating managers normally include careful estimates of the required outlays and the expected benefits.

There are, of course, psychological advantages in fixing a point in time when managers are forced to turn their thoughts to the extended future as contrasted with a general and probably ineffective exhortation to think of innovation. This procedure serves as a control system to guarantee that innovation is not completely forgotten. Furthermore, by pulling all the proposals together it facilitates corporate planning in that it provides better information for both project selection and funding. Inconsistencies certainly occur more often if long-range planning is done on a piece-meal basis. Moreover, the selection will be worse if all the competing projects are not evaluated simultaneously, and the cost of financing the projects will be prohibitive if management enters the financial markets frequently for small amounts of money.

3. Uniform Reduction in Standards and Budgets. A simple method for reconciling standards and innovations is to require a set percentage of cost reduction per year from all operating departments. There may be an advantage to having all departments advance in step, because negative covariances resulting from interdependencies are thus less likely to occur. This observation, however, applies principally to increases in output rather than to cost reductions. The latter very rarely if ever generate forces that affect adversely operations outside the cost-reducing unit, unless the cost reduction were achieved by lowering quality.

Top management may view the apparent impartiality of such uniform budget reductions as an additional pro. But this equal requirement in all likelihood is applied to unequal departments, that is to say to departments that differ both in the capacity for and difficulty in generating and implementing improvements. A second drawback of this method is that a minimum of, say, 3 per cent cost reduction per year may be converted into a maximum by those of whom it is expected. An improvement potential may be hoarded in the interest of an easy life, or, because of fears that failure to meet the preset standards will lead to punishment while an improvement over and above the set percentage will not be rewarded enough to make the game worth the risk.

To sum up, such an across-the-board procedure seems warranted only where top management has great difficulties in assessing the possibility for improvement in the individual departments and cannot motivate its lower-level managers to do what is within their power.

4. Separation of the Components of Progress Reports. It is important to establish a system which will keep track of the effect of innovations at all levels of the organization. That is, expected returns by categories should be established and compared to actual returns. This trivially obvious sounding method often is either not carried out in practice at all, or applied at some levels only. The information system of the firm must measure and provide data on a continuous basis for "managerial performance evaluation" and "activity evaluation"[12] if it is to motivate identification of cause and effect relationships.

[12] These terms are borrowed from Gordon Shillinglaw, Cost Accounting: Analysis and Control, Richard D. Irwin, Inc., Homewood, Illinois, 1961, page 694 ff, who strongly advocates such a separation.

The implementation of this seemingly simple proposal is made difficult by the fact that accounting is done by organizational units (cost centers, profit centers) and, within organizational units, by cost elements, rather than by projects. Thus, comparison of the results of an organizational unit with the results of the same unit for the preceding years (or even with the budget of the same year) permits no easy separation of the impact of the various innovative activities from each other, or of all such activities from changes in the environment or in the efficiency of personnel at all levels. Quite aside from accounting difficulties, which may possibly be reduced by decreasing costs of data processing, the separation is not easy because the success of one innovative activity is often dependent on the institution of others. Still, estimates, say by the managers of the unit when a change is instituted, are to be preferred to no attempt at evaluation. The difference in the results from one year to the next, although not absolutely precise is finite. If, therefore, the operations management estimates the consequences of innovations and learning then the residual can be compared with the estimate of the impact of environmental changes as established by the next higher echelon. This procedure bars overestimates of the success of innovative activities.

5. Tests for Statistical Significance. What we will now suggest in this sequence of steps that management can take to encourage change within standardized settings is found less frequently even in well run companies. When a process is standardized, or at least, when a standardized process has been observed for a while, an attempt should be made to determine

what constitutes a significant variance in the statistical sense.[13] The purpose is to set limits for the process, and as long as actual results stay within these limits, no action is taken.[14]

We must stress at this point that there is no need to use the same limits--say two standard deviations--for all purposes and items. Such behavior would be undesirable. For example, the limits for the manager in charge might be much narrower than those used by his superior, in order to give the manager of operations room (and time) within which his action can take hold. Also for critical items the point of action will be reached earlier than, say, for overusage of paper clips.

A system such as the one described here is used in many cases at present but only in an intuitive way. It appears to us as unreasonable, however, to believe that an operations manager is clearly aware of the significance levels of all variances and it is absurd to expect that of his superior. If they differ in their feelings about what is significant, needless frictions ensue. In addition, both will be unaware in many cases that operations are out of control until extensive damage has been done. It is for these reasons that we believe purely intuitive systems are not adequate in cases where satisfactory formal decision rules can be obtained.

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[13] This proposal has been made in much greater detail by one of the authors: Zenon S. Zannetos, "Toward A Functional Accounting System, Accounting Variances and Statistical Variance Analysis", Industrial Management Review, MIT, Spring 1966 (forthcoming); also see "Standard Cost as a First Step to Probabilistic Control" op. cit.

[14] The concept is amenable to refinement. A more or less steady approach to the limit may trigger action before it is reached. The action may be initiated either by the manager in charge or by an automated system on the basis of prestored heuristics.

We suspect that in establishing the significance of variances the organization will encourage innovation at the operational level by directing attention away from the negative variances and placing more emphasis on the favorable change in the average performance.

6. Recognition of the Probabilistic Nature of Innovations. The establishment of significance levels does not necessarily imply that management should delegate control to an automated system under all circumstances. They must recognize the desirability for flexibility because of the probabilistic nature of the results of innovations and the fact that the latter aim at changing the standards. If, therefore, a manager is about to experiment, say, on improvement of an important process, he should be freed of the standards to a degree and a time he himself suggests. In case the consequence of strong variances for other parts of the organization are very pronounced, top management might request the experimentor to put subjective probabilistic estimates on the variances or it might ask him to delay such a change or even forbid it.[15] Otherwise he should be judged on the basis of his innovative planning and the long-run improvement of the mean. It is, in our opinion, very discouraging to be called on the carpet for single failures.

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[15] One of the authors had experience with a case where such advance warning was not given. A department improved its production by almost 100 per cent within one month with the results that all other users of the same semi-finished materials had to curtail there operations and additional material had to be bought at premium prices and to be shipped at premium freight rates. Advance warning was not given because the department manager felt with some justification that, had he estimated 100 per cent improvement but achieved only say a 60 per cent improvement, he would not have received any credit but would rather be questioned why he fell short of his estimate.

An advance warning of impending changes through experimentation serves the double purpose of not applying standards for performance evaluation where the process to which they are applied is being changed, i.e., not applying them where they are in fact not applicable, and permitting reconciliation of interdependencies between departments. Building up of buffer inventories both at the input and output stage of the affected department is probably the most simple approach to the creation of the necessary contrived independence.

7. Incorporation of Functional Relationships into the Accounting System. A more radical departure from existing systems is a 'functional' accounting system.[16] By this we mean an information system which traces interdepencencies between subunits of the organization in the form of functional relationships, stored in the system itself. We can see at least four areas where such a system would mean progress.

(a) Control, both in the sense of performance evaluation and use of feedback signals for operational controls: A functional information system hopefully would allow to trace deviations of actual results (cost and quantities) to other organizational units in so far as they cause them, permitting assignment of responsibility for purposes of evaluation, motivation and learning. This should induce department heads to desist from behavior which gives rise to increased costs elsewhere without offsetting benefits for the organization as a whole. The system thus would give a better signal of the sensitivity of the objectives of the firm to variations in performance in individual departments than a simple accounting

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[16] See also Zenon S. Zannetos, "Measuring the Efficiency of the Organization Structure" MIT, Sloan School of Management, Working Paper 117-65 and "Toward a Functional Accounting System" op. cit.

variance would do. Traditional accounting variances at best trace the impact of actions within a department. Even within a department, however, often two or more variances may be functionally related but traditional variance analysis will fail to indicate these relationships and thus may lead to non-optimal corrections.[17]

(b) Planning: The system allows management to trace the effects of contemplated actions on organizational units other than the one immediately affected (simulation). Estimates of such effects are made now at least in well managed firms for major changes, but mostly on an *ad hoc* basis. The advantage of a functional system is that it provides *an algorithm* for deriving the consequences of contemplated actions. The thinking through of relationships is done once, rather than at every change, and the intelligence is stored in the algorithm hopefully providing the executive with more time for planning of long-range changes. This approach is also conducive to internal consistency between actions and overall objectives, and makes coloration of estimates by enthusiasm more difficult.

The next two areas in which a functional accounting system may be of help, go beyond short-run planning and control. These are:

(c) Design and improvement of the organization: In cases where it turns out that several units are strongly dependent upon each other and only weakly on the rest within an organization, planning may be made more efficient and

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[17]For example, unfavorable labor usage variances may have been incurred in order to reduce consumption of materials. The sum of labor and material variances may be favorable, but the connection is not normally pointed out by the traditional accounting system and managerial attention will most likely be directed toward elimination of the unfavorable labor usage.

smooth by perhaps grouping them together under one head or instructing them to plan jointly. Covariance analysis may suggest to us whether a unit has the power to interfere destructively with other units (which thus are dependent on it) without offsetting possible benefits from favorable covariances. In such case isolation through buffer inventories may be indicated.

The system described here encourages innovation since it reduces the likelihood of unanticipated side effects in the performance of other departments. The latter, if not shielded from the consequences of other managers' experimentation, might strongly object against a change once it is made, with the result that the innovating department is discouraged from further innovations, because it has no way of foreseeing the (adverse) consequences.

(d) Standards and controls at higher levels: The functional information system to the extent that it helps establish cause and effect relationships at low levels, will facilitate carrying control-through-standards to higher levels in the organization and its application to more difficult problems than those to which they have been applied heretofore. We realize, that at present such an extension is no more than a pious wish.

Finally, two comments relating to the functional accounting system:

1) The number of possible relationships among even a fairly small number of variables or activities is close to infinity. In order therefore to initiate a system, as much use as possible must be made of _a priori_ knowledge derived from experience or the dominant technology. Such knowledge in many cases would specify the functional forms with the parameters to be derived by the system itself.

Statistical techniques, and in particular covariance analysis, should prove very powerful and valuable tools in the implementation of functional accounting systems. We hasten to point out, however, that covariances are not a perfect measuring implement in that they cannot encompass more than two dimensions and must be stratified to point out asymmetric relationships. The choice of performance criteria is not as easy as it may appear to be on the surface because the consequences of variations in performance are normally multidimensional.[18]

2) The system will be incomplete without a mechanism that updates the parameters and even the relationships themselves as (a) the environment changes, (b) the process improves (the mean increases) and (c) the process comes more closely under control (the variance decreases). This implies that the model must be able to adapt in response to any changes in the real world generated either through its very application or through exogenous forces.

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[18]To illustrate this point let us assume that the output of Department A feeds into B and that of the latter into C. Suppose now that for some reason Department A produces more than expected and more than B can handle. The inventory between A and B increases, so do the costs of A or B depending on who is in charge of the inventory. There is no further effect on B and no effect at all of C. Department D which uses the same transportation facilities as A, but is otherwise unrelated to A, B, or C, may have difficulty in getting its raw materials since the transport system is overloaded, so its performance is negatively affected by a positive variation in the output of A. Alternatively, let us assume that Department A's production falls short of expectations. B's production and C's may have to stop, but D is not affected at all. To guard against such an interruption of production by B and C buffer inventories may be increased since the incremental costs per unit addition to normal inventory are likely to be much less than the cost of idle capacity in B and C. This is what we mean when we point out that the effect of a movement of a variable from plan is dependent not only on the origin but also on the size and the direction of the deviation.

Conclusion

The last fifteen years have brought us great progress in many areas of management, such as forecasting, operations research as applied to relationships between segments of the firm, increased knowledge of the research process, better understanding of the control process and its impact on engineering systems and human behavior. Incorporation of such new knowledge of causal and stochastic relationships into the information and control system permits us to extend managerial control to variables and relationships that were heretofore considered beyond its scope. Hence operations at higher levels of management become standardizable, that is to say more predictable in their outcomes. If this is generally true, we can expect that competitive pressures will be created which will reduce returns as pointed out in this article. The alternative for a management that wishes to maintain profits is to venture into areas of which even less is known. The same uncertainty that once attached to a change of a given product, for example, may now or in the future attach to the development of an entirely new product or process.

Thus, the proverbial invisible hand may be guiding us into more and more thorny problems as better solutions to the more obvious problems become exhausted and problem solving becomes refined. Stagnation of our economy after solution of the more simple problems may thus be stayed. It is here that our paper has tried to make a contribution.

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